PASSENGER CARS

Overall Trends

1 Introduction

Despite an economic downturn in some emerging countries due to drops in crude oil prices or poorer exchange rates, the strong economic recovery in North America and Western Europe, as well as the increase pace of market expansion in China due to measures to stimulate demand, have resulted in an overall growth of the 2016 global automobile market compared to the previous year. In North America, sales continued to decline in the passenger vehicle category, but exhibited strong growth in the light truck category, which includes SUVs. In terms of total demand, continued growth in Canada stood in contrast to a slowdown and leveling off of growth in the United States. In China, a significant rise in sales of Chinese brand vehicles spurred the growth of the market as a whole.

In the 2016 Japanese automobile market, the effects of the April 2015 increase of the mini-vehicle tax rate continued to make itself felt with a decline in sales of mini-vehicles declined, but this was countered by higher sales of ordinary passenger cars stemming from the introduction of new models, resulting in a very small overall market growth.

2 Production, Sales, and Exports

2. 1. Production in Leading Manufacturing Countries

The production of passenger cars by major countries around the world was 72.11 million vehicles, an increase of 5.1% over the previous year. China, with a growth rate of 15.5% representing a major expansion of approximately 3.3 million additional vehicles, led global production (Table 1). In contrast, production in Brazil shrunk by 11.9% over the previous year, representing a decrease of 240,000 vehicles. In North America, where the rise in demand is centered around the light truck category, which encompasses SUVs, the previous year's drop in production in the passenger vehicle category remained pronounced this year.

The ranking of passenger vehicle production by manufacturer stayed the same as in 2015, with the Hyundai Group's South Korean production, Toyota Motor Corporation's Japanese production, and the Volkswagen Group's German production occupying the top three ranks (Table 2). They were followed by BMW's German production, Daimler's German Production and Mazda Motor Corporation's Japanese production, maintaining the same ranking as last year until Rank 6. The considerable expansion of GM's American production, along with the Japanese production of Nissan Motor Company and Honda Motor Co., Ltd. growing to double-digit figures, were also notable, but were contrasted by considerable drops in the Japanese production of Suzuki Motor Corporation and Mitsubishi Motors.

2. 2. State of Japanese Vehicle Production, Exports, and Sales

2. 2. 1. Production

The significant drop in demand caused by the mini-

Table 1 Passenger car production in leading manufacturing countries.

		2016	2015	Compared to previous year (%)
Japan		7 873 886	7 830 722	100.6
U.S.		3 934 357	*4 162 808	94.5
Canada		802 057	888 565	90.3
EU		16 786 957	*16 324 423	102.8
	Germany	5 746 808	*5 708 138	100.7
	UK	1 722 698	1 587 677	108.5
	France	1 626 000	*1 555 000	104.6
	Italy	713 182	663 139	107.5
	Spain	2 354 117	2 218 980	106.1
South Korea		3 859 991	4 135 108	93.3
China		24 420 744	*21 143 351	115.5
India		42 008	*19 346	217.1
Brazil		1 778 464	*2 017 639	88.1
World total		72 105 435	68 604 137	105.1

Note 1) Preliminary figures announced by the International Organization of Motor Vehicle Manufacturers (OICA)
Note 2) * denote revised values
Note 3) The 27 EU countries.
Note 4) The number of vehicles for the U.S. and Canada excludes SUVs and other models considered trucks in those countries.

Table 2 Passenger car production according to manufacturer and country.

Ranking (Previous year)	Manufacturers	Country	2016 (Units)	2015 (Units)	Compared to previous year (%)
1 (1)	Hyundai group	South Korea	2 891 032	3 183 455	90.8
2 (2)	Toyota	Japan	2 847 367	2 827 349	100.7
3 (3)	VW group	Germany	2 325 447	2 327 541	99.9
4 (4)	BMW	Germany	1 190 935	1 153 283	103.3
5 (5)	Daimler	Germany	1 066 249	991 313	107.6
6 (6)	Mazda	Japan	967 510	955 961	101.2
7 (12)	GM	U.S.	864 779	725 535	119.2
8 (9)	Nissan	Japan	835 058	755 742	110.5
9 (7)	PSA	France	829 419	843 349	98.3
10 (11)	Honda	Japan	820 226	730 493	112.3
11 (8)	VW Spain	Spain	745 863	775 893	96.1
12 (14)	Subaru	Japan	727 741	709 749	102.5
13 (15)	Honda America	U.S.	686 378	678 828	101.1
14 (17)	Toyota	U.S.	676 970	629 088	107.6
15 (10)	Ford Germany	Germany	670 376	743 401	90.2
16 (18)	FCA	Italy	657 995	622 222	105.7
17 (13)	Suzuki	Japan	580 389	712 070	81.5
18 (19)	GM Daewoo	South Korea	569 394	600 961	94.7
19 (20)	Daihatsu	Japan	562 323	530 784	105.9
20 (16)	Mitsubishi	Japan	555 018	635 441	87.3

Source: Automobile manufacturers association in each country and automaker public relations material

Table 3 Passenger car production in Japan.

	2016	2015	Compared to previous year (%)
Ordinary cars	4 999 566	4 744 471	105.4
Compact cars	1 610 486	1 555 548	103.5
4-wheeled mini-vehicles	1 263 834	1 530 703	82.6
Total	7 873 886	7 830 722	100 .6

Source: Japan Automobile Manufacturers Association (JAMA)

Table 4 Number of passenger cars exported from Japan according to destination.

	2016	2015	Compared to previous year (%)
North America	1 868 638	1 719 428	108.7
Europe	803 978	717 980	112.0
Oceania	346 978	344 344	100.8
Asia	434 897	382 586	113.7
Middle-East	382 065	504 159	75.8
Central America	135 832	132 446	102.6
South America	86 317	104 377	82.7
Africa	57 424	61 898	92.8
Others	2 367	2 785	85.0
Total	4 118 496	3 970 003	103.7

Source: Japan Automobile Manufacturers Association (JAMA)

vehicle tax increase in April 2015 continued to affect passenger vehicle production in Japan throughout 2016, resulting in a major decline in production, which fell to 82.6% of the previous year (Table 3). At the same time, production of ordinary and compact cars expanded slightly, and at 7.87 million vehicles, the production and registration total for mini-vehicles essentially remained the same.

2. 2. 2. Exports

The key role played by the strong yen pushed the number of passenger cars exported in 2016 up slightly to 4.12 million vehicles, representing103.7% of the figures for the previous year (Table 4). Higher exports to North America, Europe, and Asia—primarily China—were the main drivers of the overall increase. The strong demand for light trucks, including SUVs, in North America was accompanied by an increase in exports from Japan.

Table 5 Passenger car sales in Japan.

	2016	2015	Compared to previous year (%)
Ordinary cars	1 490 216	1 354 541	110.0 %
Compact cars	1 311 275	1 349 944	97.1 %
4-wheeled mini-vehicles	1 344 968	1 511 404	89.0 %
Total	4 146 459	4 215 889	98.4 %

Source: Japan Automobile Manufacturers Association (JAMA)
The classification criteria of the sales statistics are based on the license plate number.

2. 2. 3. Sales

Sales of passenger cars in Japan dropped slightly to 4.146 million vehicles, or 98.4% of the previous year (Table 5). Still affected by the tax increase, mini-vehicles sales continued to decline, falling to 89% of the previous year, and sales of compact cars also decreased somewhat, to 97.1% of the previous year. However, strong sales of new ordinary passenger car models launched in the latter half of 2015 led to a growth of 110% compared to the previous year, resulting in only a small decline in overall sales.

2. 2. 4. Used vehicle sales

The number of used vehicles sold in 2016 was virtually unchanged at 99.8% of the previous year, and has remained at the 5.6 million vehicle level since 2012 (Table 6). Matching the trend observed for new vehicles, sales of ordinary passenger cars rose by 3.6%, while those of compact cars and mini-vehicles dropped by 2.4% and 1.3%, respectively.

2. 2. 5. Imported vehicle sales

Total sales of imported vehicles in 2016 rose to 104.6% of the previous year, an increase of 328,000 vehicles (Table 7). Sales continued to rise for most of the top ranking importers, particularly Mercedes-Benz and BMW, but declined for Volkswagen and Audi, which is part of the Volkswagen Group. Swapping places with BMW and dropping to third place, Volkswagen fell in rank for the second consecutive year. In addition, Ford sales declined considerably compared to the previous year following the announcement that it would withdraw from the Japanese market.

2. 3. Vehicle Sales in Markets outside Japan

Global markets in 2016 were marked, among major countries, by the stalled economic recovery in Brazil causing a continued decline in sales, which plummeted to 79% of the previous year (Table 8). In contrast, the tax rebate policy to stimulate sales in effect in China since October 2015 has proven effective, boosting sales to 115% of the previous year. European countries exhibited expanded sales across the board. In North America, sales in the passenger vehicle category, at 91 to 93% of the previous year, have continued to decrease, but significant growth in the light truck category, which includes SUVs, has brought sales to record levels in both countries for the combined passenger vehicle and light truck catego-

Table 6 Used vehicle sales in Japan.

	Ordinary cars	Compact cars	4-wheeled mini-vehicles	Total	Proportion of previous year (%)
2006	1 959 739	2 304 226	2 033 569	6 297 534	99.1%
2007	1 810 596	2 105 122	2 022 866	5 938 584	94.3%
2008	1 728 090	1 944 766	1 995 333	5 668 189	95.4%
2009	1 619 370	1 855 071	1 864 874	5 339 315	94.2%
2010	1 592 110	1 816 696	1 873 466	5 282 272	98.9%
2011	1 542 614	1 733 519	1 906 523	5 182 656	98.1%
2012	1 688 606	1 826 335	2 133 725	5 648 666	109.0%
2013	1 666 732	1 740 725	2 255 560	5 663 017	100.3%
2014	1 630 421	1 653 214	2 367 235	5 650 870	99.8%
2015	1 668 429	1 602 719	2 354 077	5 625 225	99.5%
2016	1 729 194	1 564 982	2 322 533	5 616 709	99.8%

Sources: Japan Automobile Dealers Association (JADA) and the Japan Light Motor Vehicle and Motorcycle Association

Table 7 Imported vehicle sales in Japan.

Ranking (Previous year)	Manufacturers	2016 (Units)	2015 (Units)	Compared to previous year
1 (1)	Mercedes-Benz	67 378	65 159	103.4
2 (3)	BMW	50 571	46 229	109.4
3 (2)	VW	47 233	54 765	86.2
4 (4)	Audi	28 502	29 414	96.9
5 (5)	BMW MINI	24 548	21 083	116.4
6 (6)	Nissan (vehicles produced outside Japan)	17 824	20 481	87.0
7 (7)	Volvo	14 553	13 510	107.7
8 (8)	Jeep	9 388	7 129	131.7
9 (16)	Suzuki (vehicles produced outside Japan)	9 026	2 953	305.7
10 (11)	Peugeot	7 403	5 906	125.3
11 (9)	Porsche	6 887	6 690	102.9
12 (10)	Fiat	6 717	6 032	111.4
13 (12)	Renault	5 303	5 082	104.3
14 (14)	Mitsubishi (vehicles produced outside Japan)	4 637	4 102	113.0
15 (20)	smart	4 508	1 012	445.5
16 (15)	Land Rover	3 165	2 979	106.2
17 (19)	Jaguar	2 883	1 349	213.7
18 (13)	Ford	2 143	4 856	44.1
19 (17)	Citroën	2 009	1 978	101.6
20 (18)	ABARTH	1 857	1 472	126.2
	Total (including ranks 20 and below)	327 607	313 081	104.6

Source: Japan Automobile Manufacturers Association (JAMA)

Table 8 Passenger car sales in leading manufacturing countries and share of Japanese vehicles.

	Total passenger car sales 2016	Japanese vehicles within the total (share of Japanese vehicles)	Total passenger car sales 2015	Total passenger car sales Compared to previous year
Japan	4 146 459	3 818 852 (92.1%)	4 215 889	98%
U.S.	6 873 158	3 108 314 (45.2%)	*7 516 826	91%
Canada	659 525	286 458 (43.4%)	*711 695	93%
Brazil	1 676 717	334 934 (20.0%)	2 122 956	79%
China	24 376 902	3 937 535 (16.2%)	21 146 320	115%
India	2 966 637	1 741 243 (58.7%)	2 772 269	107%
EU+EFTA total	15 116 344	1 963 535 (13.0%)	14 182 584	107%
UK	2 692 786	431 808 (16.0%)	2 633 503	102%
Germany	3 351 607	313 369 (9.3%)	3 206 042	105%
France	2 015 177	198 927 (9.9%)	1 917 226	105%
Italy	1 824 968	182 058 (10.0%)	*1 575 737	116%

Source: Automobile manufacturers association in each country
Note 1) Japanese vehicles refer to all Japanese brand vehicles and include those produced outside Japan.
Note 2) The number of vehicles for the U.S. and Canada excludes SUVs and other models considered trucks in those countries (Source: Ward's).
Note 3) Calculated from the 26 countries in the EU and 3 countries in the European Free Trade Association (EFTA: Iceland, Norway, and Switzerland) (source: European Automobile Manufacturers' Association (ACEA)).

ries. However, the U.S. market started leveling off in 2016.

3 Product Technology Trends

The product technology trends observed in ordinary and compact cars, as well mini-vehicles, introduced in 2016 in Japan by Japanese manufactures have been singled out and summarized (Tables 9 and 10). This summary covers new models (including the adoption of new power trains or new vehicle body structures) and completely redesigned vehicles.

3. 1. Trends by Category

In 2016, 18 new ordinary and compact car models, as well as 4 new mini-vehicle models, were launched in the Japanese market. These include original equipment manufacturing (OEM) models. Eleven new ordinary and compact car models, and four new mini-vehicle models, were introduced. Seven completely redesigned ordinary and compact car models were also introduced.

Of the 18 new ordinary and compact car models, seven were HEVs.

The addition of electrification technologies continued to advance, with Nissan adding EV variants of their existing models and Toyota adding hybrid variants of their existing models. For its part, Honda brought a fuel cell vehicle in the market.

3. 2. Fuel Efficient and Environmentally Friendly Technologies

As CO_2 regulations become stricter in various countries worldwide, manufacturers continued to pursue advances in fuel efficient and environmentally friendly technologies in 2016. Fuel efficient and environmentally friendly technologies continue to attract growing public interest, and represent crucial technologies for automakers.

The spread of electrification technologies and endeavors to develop new energy power trains (fuel cells) remain at the forefront of such technologies. A broad range of electrification technologies, including systems where the internal combustion engine (ICE) is used as a generator acting as the power source for the motors, systems that also provide a motor mechanism that assists the ICE, and mild hybrid systems that use the ICE as a primary source of power in conjunction with mechanisms to support energy recovery, low-speed cruising, and engine starts, are being introduced in the market.

The use of high compression ratio technology, CVTs, and start-stop system mechanisms has also continued to spread. As safety and other systems become more extensive and standardized, models offering expanded interior space while reducing weight by 100 kg over the previous generation have entered the market. Consumers want weight reduction technologies that do not sacrifice safety, fun, interior space, seat layout, or user friendliness, and such technologies remain a cornerstone of fuel efficiency improvement. Advances in fuel efficient and environmentally friendly technologies have allowed some models to meet the 2020 fuel efficiency standard.

3. 3. Safety Technologies

In addition to the technologies that improve fuel efficiency, advanced safety technologies have also been seen a steady growth in adoption.

Since 2016, the evaluation of the performance of braking systems that mitigate pedestrian injuries has been added to the active safety evaluation in the Japan New Car Assessment Program (JNCAP). This has led to the introduction of models with higher active safety performance with respect to pedestrians. Progress was made in standardizing advanced safety systems in conjunction with refinements in safety performance such as the adaption of collision avoidance assist brakes to work at higher vehicle speeds.

The technical field of pedestrian safety, in particular, saw the introduction of technology to protect pedestrians, such as Subaru making pedestrian airbags standard equipment for the first time in Japan.

The installation of control systems that suppress start-offs to reduce accidents cause by pedal misapplication in automatic vehicles, a topic of growing public interest, has become more common.

Mini-vehicles are incorporating even more advanced safety technologies than ordinary and compact cars, and models featuring pedestrian injury mitigation brakes as standard equipment have become available.

Table 9 Product technology trends in passenger cars produced in Japan in 2016

Release date	Vehicle model	Manufacturers	Major details
January 14	Delica D:2	Mitsubishi	Full model change Reduces weight extensively while expanding cabin space. Equipped with a newly developed 1.2 -liter engine and mild hybrid system, providing both fuel efficiency and acceleration performance. All models have the latest e-Assist active safety technology as standard equipment. A new platform was developed, minimizing the engine compartment with an optimal layout for the new lightweight downsized 1.2 -liter engine. The wheelbase was also extended (30 mm longer than the previous generation) to ensure occupant space. Weight has been reduced by 100 kg compared to the previous generation, and the adoption of a new highly efficient, lightweight downsized engine and a mild hybrid system achieves a fuel economy of 27.8 km/L (2 WD).
February 18	Ignis	Suzuki	New model This new genre of compact crossover is a fusion of sports utility vehicles (SUVs) and compact cars. The packaging offers a compact body size and higher eye point, and expanded road clearance gives driving performance suited to snowy or rough roads. All models feature a mild hybrid system and the K12D Dual Jet engine. Fuel economy is 28.8 km/L (hybrid MG 2 WD). Safety systems include dual camera brake support, SRS curtain airbags, and front seat SRS side airbags.
March 9	Baleno	Suzuki	New model Two grades offered: one with a 1.0 -liter turbo engine, and one with a 1.2 -liter naturally aspirated engine. Fuel economy is 20.0 km/L for the 1.0 -liter turbo engine version, and 24.6 km/L for the 1.2 -liter naturally aspirated engine version. Newly developed lightweight, high rigidity platform. Adopts advanced safety systems that include a collision mitigation system, and a following function that maintains distance from the preceding vehicle by accelerating and decelerating automatically.
March 10	Clarity Fuel Cell	Honda	New model New fuel cell vehicle, featuring high practicability and sophisticated appeal, aimed at popularizing FCVs. The fuel cell powertrain has been downsized and mounted under the hood, making it the first sedan FCV in the world with room for five adult passengers. The adoption of a 70 MPa high-pressure hydrogen fuel tank, a more high efficiency powertrain, and reduction in the amount of energy required for driving all contributed to extending the driving range for a single refill (reference value) by some 30 %, to approximately 750 km. It can become a "drivable electric power source" and provide electrical power if used in conjunction with a portable external electric power supplier. Maximum motor output of 130 kW/4 ,501 –9 ,028 rpm, and maximum torque of 300 N•m/0 –3 ,500 rpm.
April 12	Boon	Daihatsu	Full model change Model developed with the goal of raising the standards for compact cars as a whole by bringing the accumulated technology developed in mini-vehicles and the concept a product proposal matching user needs and closely tied to everyday life to compact cars. The combination of the 1.0-liter 1 KR-FE engine and a CVT achieves a fuel economy of 28.0 km/L (2 WD). The compression ratio was raised to 12.5 from the previous 11.5. Adopts the Smart Assist II collision avoidance assist system.
April 12	Passo	Toyota	Full model change (OEM of Daihatsu Boon). All grades combine a 1.0 -liter engine with a CVT. Fuel economy is 28.0 km/L for the 2 WD grade, and 24.4 km/L for the 4 WD grade. Driving performance improved through features such as a lighter and stiffer body and strengthened chassis. Collision avoidance system (Smart Assist II), Collision warning function (vehicles and pedestrians), Collision avoidance support braking function (vehicles), Erroneous start prevention function (forward, reverse), Preceding vehicle departure reporting function.
April 18	Auris	Toyota	Hybrid variant introduced. Equipped with 1.8 -liter engine hybrid system (THS II with a reduction gear). Cruising fuel economy of 30.4 km/L. Achieves the 2020 fuel efficiency standard +20 % threshold. 2005 emissions standard 75 % reduction level. The engine and motor combination achieves both direct acceleration performance and superior quietness.
August 24	Serena	Nissan	Full model change Based on the "big, easy and fun" concept, development was planned to provide enjoyable and comfortable mobility to all people with features such as a large, convenient, and pleasant cabin. Adopts the ProPilot single-lane automated driving technology. On highways or other roads reserved for motorized vehicles, the system controls vehicle speed within the driver-set upper limit (approx. 30 to 100 km/h) to maintain a constant distance with the preceding vehicle, and provides support for driving in the middle of the lane. Fuel economy is 17.2 km/L.
September 16	Freed	Honda	Full model change Offers versatile seating layouts adaptable to various uses anytime, anywhere, by anyone, based on a concept suggesting wonderful mobility seven days a week. Includes the Honda Sensing advanced driving safety support system. Provides optimum settings for carrying many people, and achieves excellent balance between driving performance and fuel economy. Hybrid vehicles: Equipped with the Sport Hybrid Intelligent Dual Clutch Drive (i-DCD) system, consisting of a 1.5 -liter gasoline and a 7 -speed dual clutch transmission (DCT) with a built-in motor. Fuel economy is 27.2 km/L. Gasoline vehicles: 2.5 -liter direct injection DOHC i-VTEC engine and high efficiency CVT. Fuel economy is 19.0 km/L.

Table 9 Product technology trends in passenger cars produced in Japan in 2016 (cont.)

Release date	Vehicle model	Manufacturers	Major details
October 25	Impreza	Subaru	Full model change Aiming to offer customers security and delight, this model introduces the next-generation Subaru Global Platform and other new technologies. It improves overall safety performance as well as the dynamic and static feel. All versions include a pedestrian airbag and EyeSight (version 3) as standard equipment. In comes in the Sport (5 -door hatchback) and G4 (4 -door sedan) body types, and offers newly developed 2.0 -liter and 1.6 -liter direct injection naturally aspirated engines. Built according to the new "dynamic and solid" design philosophy.
November 2	Note e-Power	Nissan	EV grade added. Driven by the electric motor in the new e-Power powertrain using electricity generated by the mounted gasoline engine. Offers highly responsive acceleration fully powered by motor drive, and is also quiet. The engine stops during deceleration, and regenerative power generation charges the high voltage battery. External charging is unnecessary, and driving based only on gasoline refueling offers a fuel economy of 34 to 37.2 km/L. The Intelligent Around View Monitor (with a function to detect mobile objects) and Smart rearview mirror (with a function to display the images from the Intelligent Around View Monitor) are available as options.
November 9	Thor	Daihatsu	New model Compact exterior dimensions provide maneuverability on par with a mini-vehicle while nevertheless offering a relaxed interior space. Offers seating arrangements and luggage space adaptable to a variety of situations. Broad range of accessories, including a rotary cup holder, a large assist grip (with child grip) for getting in and out, and a TFT color multi-information display. Equipped with the 1 KR-FE 1.0 -liter inline 3 -cylinder engine or the newly developed 1 KR-VET 1.0 -liter inline 3 -cylinder turbo engine, it features a high rigidity body and adopts the D suspension. Fuel economy is 24.6 km/L (1 KR-FE (2 WD)).
November 9	Tank/Roomy	Toyota	New model (OEM of Daihatsu Thor) Based on a concept dubbed "1 LD car", which combines a spacious interior with flexible driving, the new type of tall 2 -box vehicle represented by these models are perfect for a broad variety of customer everyday needs, particularly families with children.
November 21	Justy	Subaru	New model (OEM of the Daihatsu Thor) Developed under a concept called "Big Pleasure Compact", this compact car fully satisfies the wide-ranging everyday needs of customers. It has a small turning radius of 4.6 m and body dimensions keeping it within the 5 -series license plate category, while offering a spacious interior. A 1.0 -liter naturally aspirated engine and a newly developed 1.0 -liter turbocharged engine are available. A start-stop system is standard equipment for all grades, and fuel economy is 24.6 km/L. Safety-wise, the Smart Assist II system is standard equipment for all grades, and the newly developed body can withstand frontal offset impacts at 64 km/h. Other features include a structure that mitigates injuries to the heads or legs of pedestrians.
November 29	Solio/Solio Bandit	Suzuki	Full model change Features a compact system with motor assist and an EV mode. Offers both fuel economy and driving performance while remaining spacious. Combines a 1.2 -liter gasoline engine with a motor. Fuel economy is 32.0 km/L. Two hybrid systems: a mild hybrid system where a motor assists the engine during acceleration, and a hybrid system offering EV mode driving. The compact system improves fuel economy. In terms of safety technologies, the collision mitigation system uses a stereo camera. ASV++ rating in the 2016 JNCAP active safety performance assessment. Memory navigation system with omnidirectional monitor that shows images of the vehicle surroundings.
December 14	C-HR	Toyota	New model Second Toyota New Global Architecture (TNGA) model. Shares the platform of the Prius, the first TNGA vehicle, and pursues responsiveness, linearity, and consistency to realize the concept of "driving the way I want". Original style based on a concept called "Sensual Speed-Cross". The hybrid variant has a fuel economy of 30.2 km/L. Certified as achieving the 2020 fuel economy standards +20 % and the 2005 emissions standard 75 % reduction level. The 1.2 -liter turbocharged grade (regular gasoline) as a fuel economy of 15.4 km/L. Certified as achieving the 2015 fuel economy standards +5 % and the 2005 emissions standard 75 % reduction level.
December 20	Landy	Suzuki	New model Equipped with features such as a 2.0 -liter inline 4 -cylinder engine, the simple hybrid system, a start-stop system. Fuel economy is 16.6 km/L (2 WD). Front wheel 2 WD and full time 4 WD grades are available. The transmission is a CVT. The sliding mechanisms for the second row, which is extra long, and the third row enable a versatile seating arrangement. Two ways of opening the back door. The emergency braking system that supports avoiding collisions with vehicles or pedestrians is standard equipment for all grades. The fuel economy of the 2 WD grade has been improved through measures such as extending the stop duration of the start-stop system, and the 4 WD grade has been newly equipped with the smart simple hybrid (S-Hybrid) system.
December 22	Roadster RF	Mazda	New model Adopts a fastback style. The electric retractable roof is operated with the simple press of a switch, and a structure allowing efficient storage in the limited space available provides almost as much luggage space as in the soft top model. Uses the SKYACTIV-G 2.0 gasoline engine. An RS model even more focused on the joy of driving uses a longitudinally mounted exclusively tuned SKYACTIV-G 2.0 engine and offers exclusive seats and Brembo brakes as manufacturer options.

All fuel economy values are JC08 test cycle fuel consumption rates (verified by the Ministry of Land, Infrastructure Transport and Tourism)

Table 10 Product technology trends in mini-vehicles produced in Japan in 2016

Release date	Vehicle model	Manufacturers	Major details
August 31	Pixis Joy	Toyota	New model (OEM of Daihatsu Move Conte) Uses e:S technology to achieve a fuel economy of 30.0 km/L. All grades are eligible for the fuel-efficient car tax reduction. Equipped with the Smart Assist II collision avoidance assist system.
September 7	Move Canbus	Daihatsu	New model First mini-vehicle equipped with the Adaptive Front-lighting System (AFS). Features the Panorama Monitor. Fuel economy is 28.6 km/L (2 WD grade), making it exempt under the fuel-efficient car tax reduction, and the 4 WD grade has a fuel economy of 27.4 km/L, making it eligible for that reduction. Adopts the Smart Assist II collision avoidance assist system.
September 26	Pixis Space	Toyota	New model (OEM of Daihatsu Cast) Features such as the 2,490 mm long wheelbase provide 2,000 mm of interior space. Offers both a higher and wider cabin providing ample interior space allowing four adults to relax and sufficient luggage space. Engine variants available are the 660 cc KF engine with DVVT and the 660 cc KF engine with an intercooler-equipped turbocharger. All variants pair the engine with an automatic continuously variable transmission (CVT). The 2 WD grades (X, Custom G) are equipped with the eco-IDLE start-stop system and have a fuel economy of 25.5 km/L (CO_2 emissions: 91 g/km) in the 10-15 Japanese test cycle. All grades with the KF engine (excluding the Custom RS) achieve the 2010 fuel economy standards + 25 %. Certified as achieving the 2005 emissions standard 75 % reduction level, and compliant with the 75 % tax reduction requirements for the vehicle acquisition and motor vehicle weight taxes.
December 13	Chiffon	Subaru	New model (OEM of Daihatsu Tanto) Features sliding doors on both sides, and a passenger door with a built-in B-pillar, called the "Miracle Open Door". Achieves a wide door opening of 1,490 mm. The newly developed Smart Assist III is standard equipment on all grades. Safety has been further enhanced with the adoption of a stereo camera expanding the emergency braking operation to pedestrians and over a broader speed range, high beam assist, and other functions. Enhancements such as making the vehicle lighter and reducing aerodynamic drag through integrated molding of the rear gate and roof spoiler make all grades compliant with the 2020 fuel economy standards.

All fuel economy values are JC08 test cycle fuel consumption rates (verified by the Ministry of Land, Infrastructure Transport and Tourism)

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(6) Website of each company

Design Trends

The fusion of automobiles and IT technology became even more pronounced in 2016 also turned it into a year involving major changes in automobile design. At the same time, new approaches came to the fore as the various brands strove to express their business strategy through the power of design. This article seeks to offer an understanding of major trends by providing a sweeping view of the current context of automobile design.

1 Brand Expression

Recently, efforts aimed at making brand characteristics stand out have further intensified. The BMW Group, in particular, is one of the brands garnering attention. Celebrating its 100th anniversary in 2016, the BMW brand has a long history and used exhibition models to present its vision for the next 100 years of its three marques (BMW, Mini, and Rolls-Royce). Features such as automated driving and ride sharing send a strong brand message that builds on the tradition while looking to the future (Fig. 1).

Mercedes-Benz has also successively presented the Vi-

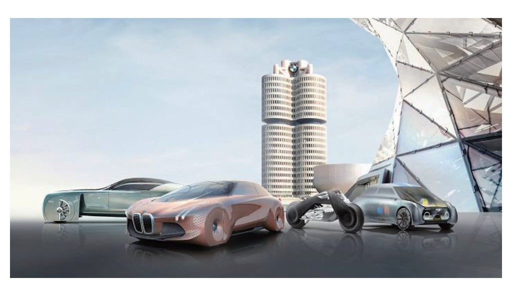

Fig. 1 BMW Group Vision Next 100

Fig. 2 Vision Mercedes-Maybach 6

Fig. 3 Vision Mercedes-Maybach 6

Fig. 4 Nissan Serena

sion Mercedes series of concept cars at international shows as a means of conveying the future of its brand. In 2016, it unveiled the Vision Mercedes-Maybach 6, a luxurious coupé (Fig. 2).

The exterior offering elegant and classical front-engine, rear-wheel drive proportions worthy of the pinnacle of Mercedes, combines with a futuristic interior that leverages IT technology to provide features such as displaying information on the windshield, to make this a high appeal concept model (Fig. 3).

2 Fusion of Automobiles and IT

One of the most significant events in Japan was the introduction of a Japanese-made vehicle featuring automated driving technology.

The launch of models such as the flagship Nissan Serena (Fig. 4) effectively made 2016 the first year of automated driving popularization. Its strategic prices finally brings automated driving within the reach of the aver-

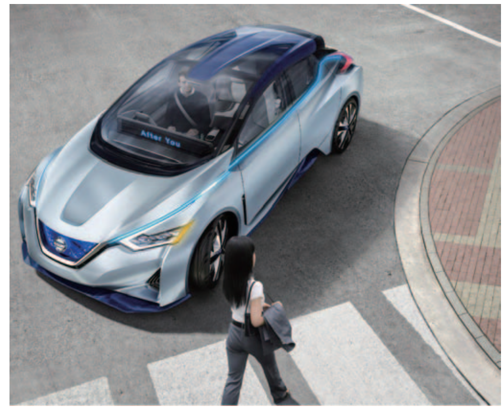

Fig. 5 Nissan IDS Concept

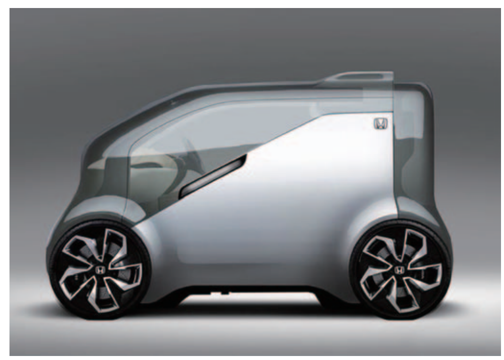

Fig. 6 Honda NeuV

age consumer.

As automated driving evolves, new issues concerning the adaptation of automobiles to urban environments are becoming apparent. The IDS Concept model (Fig. 5) unveiled by Nissan in 2015 proposed a method of communication between automobiles and pedestrians based on textual information, and this field is expected to progress further through the application of non-verbal communication and other forms of interaction that coordinate with design expression.

For its part, Honda unveiled its NeuV concept model for automated driving technology (Fig. 6) not at a motor show, but at the CES IT trade show held in the United States. More and more brands are adopting a similar approach, which is symbolic of the accelerated pace of the fusion between automobile and information technology.

3 Environmental Technology and Design

Some manufacturers are striving to express the application of environmental technology as part of new designs. Exterior design, for instance, has used highly energy-efficient LED technology in automobile lamps for a long time. More recently, numerous concepts that capi-

Fig. 7 BMW i8

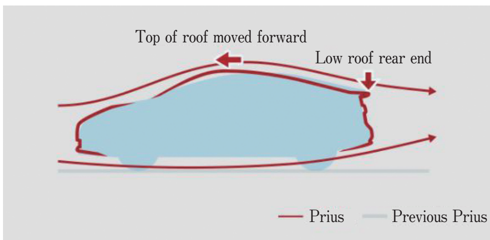

Fig. 8 Toyota Prius

Fig. 9 Toyota Prius

talize on the high degree of shape flexibility of LEDs to realize both highly innovative designs and environmental (aerodynamic) performance, such as the BMW i8 (Fig. 7), are being put forth.

The fourth-generation Toyota Prius further refines the silhouette established by the second and third generations, whose distinctive gently arched roof offers superior aerodynamics and packaging (Fig. 8). At the same time, the design is characterized by features such surfaces treated to help correct airflow set at body corners and various other locations that reflect the value placed on environmental performance permeating down to the finest detail (Fig. 9). This is also applied in the Prius PHV and Lexus LC launched in 2017 (Figs. 10 and 11).

The Aston Martin DB11 (Fig. 12) directs air through the bodywork from the C-pillar and out at the trailing edge of the trunk to improve aerodynamic characteristics without relying on supplementary aerodynamic parts such as spoilers (Fig. 13). This idea achieves both environmental performance and the elegant and clean-cut silhouette intended by the original design.

Fig. 10 Lexus LC

Fig. 11 Lexus LC

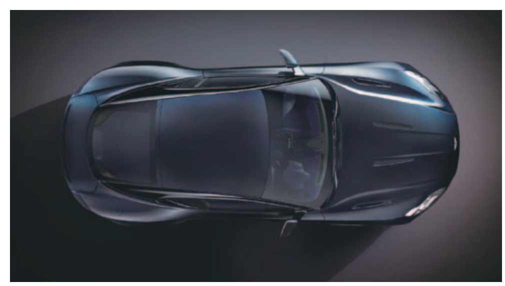

Fig. 12 Aston Martin DB11

Fig. 13 Aston Martin DB11

4 Premium Crossovers

On a global scale, the crossover category features the most active introduction of products, and as in the previous year, 2016 saw a succession of luxury model offerings by the premium brands.

Bentley launched the Bentayga (Fig. 14) crossover model which is essentially designed around a platform shared with the Q7 (Fig. 15) by Audi, a fellow member of

Fig. 14 Bentley Bentayga

Fig. 15 Audi Q7

Fig. 16 Maserati Levante

the Volkswagen Group. Each brand successfully uses its distinctive family traits and body language to skillfully express its uniqueness. The Maserati Levante is a crossover embodying the luxury of high-end Italian sports car brands as well as a sporty worldview (Fig. 16).

The world of crossovers, in particular, is demonstrating a propensity to bring out new models based on heretofore unseen combinations. In 2015, Aston Martin unveiled the DBX Concept, a crossover incorporating the features of a luxury coupé (Fig. 17). Range Rover added a new convertible model to its Evoque series (Fig. 18), creating value based on the new combination of convertibles and crossovers.

5 The Expanding Scope of Design Expression

Lexus exhibited at the Milano Design Week international design event for the tenth time. The art exhibits

Fig. 17 Aston Martin DBX Concept

Fig. 18 Range Rover Evoque Convertible

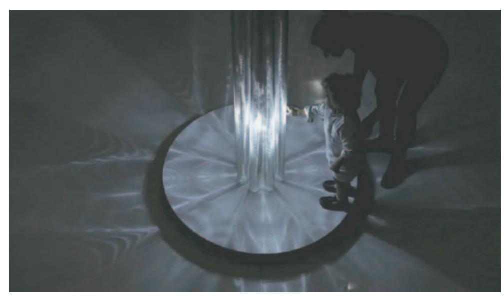

Fig. 19 Lexus Design Award 2017

blending the radical expression sought by the brand with the aesthetic sense of Japanese culture continues to convey the brand message through collaborations with artists around the world (Fig. 19).

At Mazda, the Design Division is overseeing the architectural design of the dealerships, where customers and cars meet, and developing next-generation stores. This clearly reflects the aim of clearly promoting the brand worldview not only in the design of the vehicles themselves, but also through a total design encompassing elements such as the stores presenting the vehicles and exhibition booths (Figs. 20 and 21).

6 Japanese Car Design Highly Rated Worldwide

A succession of high ratings for Japanese car design on a global scale stood out in 2016. The Mazda Roadster (Fig. 22) and CX3, along with the Jaguar XE, were the finalists for the World Car Design of the Year award an-

Fig. 20 Kanto Mazda Takatanobaba store

Fig. 21 Kanto Mazda Takatanobaba store

Fig. 22 Mazda Roadster

nounced in March 2016, which was won by the Roadster.

In addition, the Mazda RX-Vision (Fig. 23) was named Most Beautiful Concept Car of the Year at the 31st Festival Automobile International held in Paris, France.

The Nissan Vmotion 2.0 (Fig. 24) received the Eyes on Design Award at the North American International Auto Show is just one example of designs by Japanese brands drawing attention on par with that of European premium brands.

Fig. 23 Mazda RX-Vision

Fig. 24 Nissan Vmotion 2.0

7 Conclusion

Automobile design in 2016 stood out as the evolution of a means of mobility spurred by dramatic advances in information technologies such as automated driving or ride sharing. Although these trends may be prone to turning products into commodities, automobile design based on stimulating people's delight in owning beautiful cars and controlling them as desired continues to be offered vigorously. Designs by Japanese brands are being increasingly well received on the international scene, and sustaining that momentum over time will be critical.

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Body Structures

1 Trends in Body Structures

Regulations on CO_2 emissions and fuel economy are becoming more stringent year after year in an effort to halt global warming not only in developed countries, but in emerging countries as well. In Europe, the CO_2 emissions regulatory value, which was 130 g/km or less in 2015, is schedule to drop to 95 g/km in 2021 and around 70 g/km in 2025. The fuel economy regulatory value in the U.S., set to 35.5 miles/gallon (approx. 15.1 km/L) in 2016, will be raised by a factor of 1.5 to 54.5 miles/gallon (approx. 23.2 km/L) by 2025. The Chinese fuel economy target value of 6.9 L/100 km (14.5 km/L) in 2015 will increase to 5.0 L/100 km (20.0 km/L) by 2020.

This situation is prompting successive launches of new, mainly hybrid, models relying on electric power such as the Honda Odyssey and NSX, the Nissan Note e-Power, and the Toyota C-HR. This trend toward electrification is picking pace worldwide. However, electrification in addition to increasing vehicle weight due to the mounting of power units, the strengthening of the body frame to protect electrical devices such as batteries is also a factor in weight increase.

Furthermore, on the safety front, the Tenth Fundamental Traffic Safety Program issued by the Cabinet Office in March 2016[1] set the target of reducing the number of fatalities to less than 2,500 by 2020 (there were 3904 in 2016), forcing automakers to step up their efforts in that respect. Using existing technologies, measures against collisions are expected to increase the weight of vehicle bodies with a comparatively high contribution to passive safety performance.

Also, with SUV sales expanding worldwide, including in emerging countries, weight increases particular to SUVs cannot be ignored.

Avoiding the negative impact of such weight increases on fuel economy makes reducing the weight of the vehicle body a challenge that can only be met in a limited way in bodies using current steel sheets. Consequently, the use of multi-material bodies seeking to achieve further weight reduction is gaining momentum.

This article review the 2016 trends in body structure technologies with a focus on balancing body performance (including crashworthiness) and weight reduction.

2 Technological Trends Concerning Performance Requirements

2. 1. Stability and Controllability

Going beyond allowing the driver to feel the joy of controlling the vehicle as desired, stability and controllability performance is also crucial to offering safe and worry-free driving. In contrast, there is a need to underscore the fun of driving automobiles to counter the growing tendency of young people in Japan to steer away from buying cars. Conscious of these factors, automakers are engaging in carmaking focused on stability and controllability performance, as well as power performance.

For the Subaru Impreza launched in October 2016, body deformation measurements taken with a strain gauge every 1/1000 second were paired with subjective evaluations to secure both higher and continuous rigidity causing no driver discomfort and achieve a dynamic feel[2].

Fig. 1 Honda FCV[4]

2. 2. Noise, Vibration and Harshness (NVH) Performance

Expectations placed on NVH performance keep rising, and in addition to offering a higher level of quietness in the rear seats as well as in the front, a high level of quality is insisted upon.

In vehicle bodies, creatively engineering the frame and panel shapes, rather than allocating cost or mass to control vibration, has become the mainstream approach to eliminating pronounced vibration peaks. Sound absorbing and insulating materials, whose play a supplementary role, and then updated to incorporate the latest advances and efficiently set in the dash and floor panels, as well as the pillars, in accordance with the intended purpose.

The NVH performance of vehicle bodies is expected to change as electrification becomes more prevalent.

2. 3. Safety performance

With respect to passive safety performance, measures such as the revising of impact modes are being taken in various countries to strengthen passive safety assessments and reduce the number of fatalities.

The growing number of electric-powered vehicles are in no way exempt from these tougher assessments, and the Nissan Note e-Power provides an example of efficient adaptation achieved by making minimal structural modifications to the body of the gasoline engine base vehicle[3]. The Honda FCV relies on an efficient energy-absorbing structure where the front side frame, floor frame and rear subframe are connected in a straight line to protect the battery and hydrogen tank (Fig. 1)[4].

Such ingenious adaptations of body structures to new vehicle specifications such as those of electric-powered vehicles will become increasingly necessary.

3 Technological Trends to Mitigate Weight Increase and Satisfy Performance

3. 1. Steel Sheets

Although multi-material bodies have been adopted in some models, steel sheets are currently the primary material constituting the vehicle body.

Formability improvements and tailored manufacturing methods carried out with steelmaker involvement have led to a steady increase in the use ratio of ultra high tensile strength steel sheets made thinner for the purpose of reducing the weight of the vehicle body. Known examples of the adoption of ultra high tensile strength materials include the 1,180 MPa class cold rolled steel sheets primarily used to improve performance against impacts, the die quenched 1,500 MPa class material used in the B-pillar and other structural members, and the 1,800 MPa class material used in the front bumper beam.

The front pillars of the Honda NSX use a 1,500 MPa ultra high tensile pipe made with three-dimensional hot bending and direct quench (3DQ) technology to reduce weight while achieving high rigidity, superior space efficiency, and passive safety[4].

3. 2. Aluminum

First used in the top tier models of European premium car lineups, the use of aluminum in vehicle bodies has been filtering down to the middle tier of those lineups. In Japan, it can be seen in premium cars such as the Lexus LC and the Honda NSX.

The NSX raises its ratio of aluminum use through aluminum extrusions in the main frame members, a space frame structure with aluminum cast parts at the joints between members, and even aluminum panels in some of the outer panels. It also features the first automotive industry use of ablation casting technology, which provides higher ductility and strength mechanical properties than the current gravity casting process, and is used for the front and rear suspension housings[4].

3. 3. Composite Materials

Due to its mechanical properties of being light weight and strong, CFRP, a composite material consisting of plastic and carbon fiber, offers significant weight reduction potential. Consequently, it is increasingly used in vehicle bodies, particularly in BMW, Audi, and other European vehicles. In Japan, it was initially used as panel material for roofs and other parts in limited production vehicles, and following its use in the limited production Lexus LFA, it started seeing use in low-volume production in 2016 with the NSX (Fig. 2). Advances in the development of the material itself and in manufacturing process technologies have been alleviating the issues of high cost and low productivity involved in the adoption of CFRP, and its application is expected to expand further, and encompass popular cars, in the coming years.

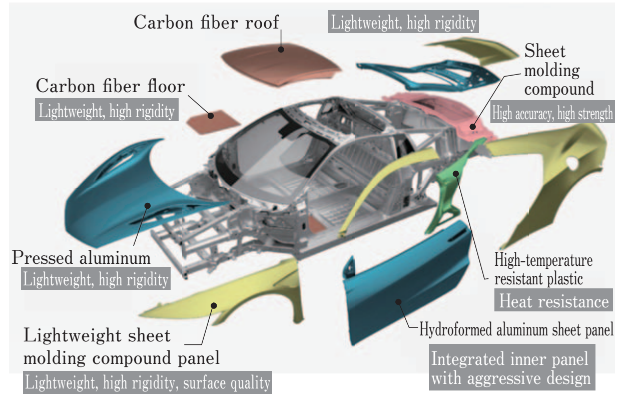

Fig. 2 Honda NSX[4]

Similarly, the Honda FCV is the first vehicle in the world to adopt a lightweight, high-strength rear bumper beam that uses GFRP, a composite material consisting of plastic and glass fiber, which offers enhanced moldability achieved through hybrid molding that layers non-continuous and continuous glass fiber[4].

3. 4. Joining

While the spot welding generally used for vehicle bodies consisting of steel sheets is a single-point joining process, the application of laser welding or continuous welding principles involving the concurrent use of adhesives is becoming more common.

At the same time, multi-material structures using lighter materials in suitable locations to reduce vehicle body weight are seeing greater adoption. Multi-material structures have prompted advances in joining technologies used to bond dissimilar materials such as steel sheets, aluminum, plastics, or CFRP. These include the use of adhesives in addition to mechanical fastening using self-piercing rivets (SPR) or flow drill screws (FDS).

Multi-material structures are likely to become more prevalent and simultaneously incorporate new materials, and new joining technologies adapted to those materials will undoubtedly be required.

Fig. 3 Toyota TNGA[5]

Fig. 4 Subaru Global Platform[6]

Fig. 5 Mazda SKYACTIV-Body[7]

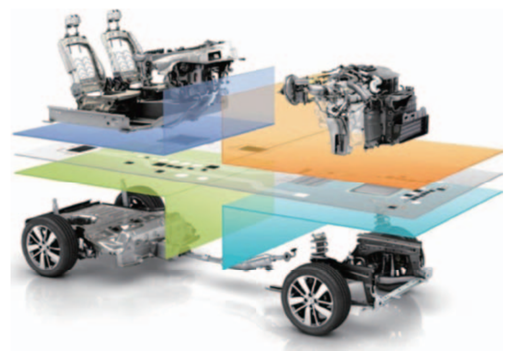

Fig. 6 Nissan CMF[8]

Fig. 7 Suzuki HEARTECT[10]

4 Platform Unification

Development efficiency must be increased and costs reduced even further to adapt to the market conditions changes mentioned in the introduction and respond to the needs of the market on issues such as safety. In that respect, manufacturers are unifying their platforms in preparation for the future, and cross-segment commonization and standardization is also being applied to vehicle body structures.

Starting with the Prius unveiled in December 2015, Toyota has been gradually adopting the Toyota New Global Architecture (TNGA) (Fig. 3) for its models. The TNGA body frame mainly consists of a new annular structure and a strong new joining structure, increased and optimized welding positions, and the setting of structural adhesives[5].

Subaru introduced the Subaru Global Platform (Fig. 4) with the Impreza announced in October 2016, and is gradually applying it to its other models. As a next-generation platform setting the course until 2025, it is adapted to upcoming electrification, and features such as the optimized frame structure and stronger joining of parts enhance the sense of dynamism and increase safety performance[6].

This concept of platform unification was adopted by Mazda with the SKYACTIV-Body (Fig. 5) first seen in the CX-5 announced in 2011[7], by Nissan with the Common Module Family (CMF) (Fig. 6) first used in the Rogue, Qashqai, and X-Trail unveiled in 2013[9], and by Suzuki with the HEARTECT, which debuted in the Alto announced in December 2014[10].

Similarly, non-Japanese manufacturers are also applying the principle of unification, as seen in the Volkswagen Group Modularer Querbaukasten (MQB)platform[11], the Volvo Scalable Product Architecture (SPA)[12], and the PSA Group Efficient Modular Platform 2 (EMP2)[13].

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